The Effect of Crown Gall Upon a Young Apple Orchard

L. Greene & I. E. Melhus

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

POMOLOGY AND
BOTANY AND PLANT PATHOLOGY SECTIONS

RESEARCH BULLETIN NO. 50
March, 1919
Ames, Iowa

March, 1919. Research Bulletin No. 50

The Effect of Crown Gall Upon a Young Apple Orchard

BY LAURENZ GREENE AND I. E. MELHUS.

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

POMOLOGY AND
BOTANY AND PLANT PATHOLOGY SECTIONS

Ames, Iowa

OFFICERS AND STAFF
IOWA AGRICULTURAL EXPERIMENT STATION

Raymond A. Pearson, M. S. A., LL. D., President
C. F. Curtiss, M. S. A., D. S., Director
W. H. Stevenson, A. B., B. S. A., Vice-Director

AGRICULTURAL ENGINEERING

C. K. Shedd, B. S. A., B. S. in A. E., Acting Chief
W. A. Foster, B. S. in Ed., B. Arch., Assistant
E. B. Collins, B. S. in A. E., B. S. in Agron., Assistant

AGRONOMY

W. H. Stevenson, A. B., B. S. A., Chief
H. D. Hughes, B. S., M. S. A., Chief in Farm Crops
P. E. Brown, B. S., A. M., Ph. D., Chief in Soil Chemistry and Bacteriology
L. C. Burnett, B. S. A., M. S., Chief in Cereal Breeding
L. W. Forman, B. S. A., M. S., Chief in Field Experiments
John Buchanan, B. S. A., Superintendent of Co-operative Experiments
R. S. Snyder, B. S., Assistant in Soil Chemistry
H. W. Johnson, B. S., M. S., Assistant in Soils
Geo. E. Corson, B. S., M. S., Assistant in Soil Survey
H. W. Warner, B. S., M. S., Soil Surveyor
M. E. Olson, B. S., M. S., Field Experiments
E. I. Angell, B. S., Soil Surveyor
J. F. Bisig, B. S., Field Experiments
O. F. Jensen, B. S., M. S., Assistant in Farm Crops
H. P. Hanson, B. S., Field Experiments

ANIMAL HUSBANDRY

H. H. Kildee, B. S. A., M. S., Chief
J. M. Evvard, M. S., Assistant Chief in Animal Husbandry and Chief in Swine Production
H. D. Van Matre, B. S. A., Supt. of Experiments in Animal Husbandry
R. Dunn, B. S., Assistant in Animal Husbandry
H. W. Vaughan, B. S. A., M. S. A., Assistant in Animal Husbandry
C. C. Culbertson, B. S., Assistant in Animal Husbandry
H. A. Bittenbender, B. S. A., Chief in Poultry Husbandry
L. S. Gillette, B. S., M. S., Assistant Chief in Dairy Husbandry
A. C. McCandlish, M. S. A., Assistant Chief in Dairy Husbandry

BACTERIOLOGY

R. E. Buchanan, M. S., Ph. D., Chief; Associate in Dairy and Soil Bacteriology

BOTANY AND PLANT PATHOLOGY.

L. H. Pammel, B. Agr., M. S., Ph. D., Chief
Charlotte M. King, Assistant Chief
I. E. Mehus, B. S., Ph. D., Chief in Plant Pathology
J. C. Gilman, B. S., M. S., Ph. D., Assistant Chief in Plant Pathology.

CHEMISTRY

A. W. Dox, B. S., A. M., Ph. D., Chief. (On leave)
W. G. Gaessler, B. S., M. S., Acting Chief
A. R. Lamb, B. S., M. S., Assistant
Lester Yoder, B. S., M. S., Assistant

DAIRYING

M. Mortensen, B. S. A., Chief
B. W. Hammer, B. S. A., Chief in Dairy Bacteriology

ENTOMOLOGY

E. D. Ball, B. S., M. S., Ph. D., Chief
Wallace Park, B. S., Assistant in Apiculture

FARM MANAGEMENT

O. G. Lloyd, B. S., M. S., Assistant
H. B. Munger, B. S., Chief

HORTICULTURE AND FORESTRY

S. A. Beach, B. S. A., M. S., Chief
T. J. Maney, B. S., Chief in Pomology
Harvey L. Lantz, B. S., Assistant Chief in Pomology
W. E. Whitehouse, B. S., Assistant in Pomology
A. T. Erwin, M. S., Chief in Truck Crops
Rudolph A. Rudnick, B. S., Assistant in Truck Crops
G. B. MacDonald, B. S. F., M. F., Chief in Forestry
Frank H. Culley, B. S. A., M. L. A., Chief in Landscape Architecture

RURAL SOCIOLOGY

G. H. Von Tungeln, Ph. B., M. A., Chief

VETERINARY MEDICINE

C. H. Stange, D. V. M., Chief

GENERAL OFFICERS

F. E. Colburn, Photographer
F. W. Beckman, Ph. B., Bulletin Editor. (On leave)

THE EFFECT OF CROWN GALL UPON A YOUNG APPLE ORCHARD

Laurenz Greene and I. E. Melhus.

INTRODUCTION.

The definite and conclusive researches of Erwin F. Smith (5), on the cause of Crown Gall (*Bacterium tumefaciens,* Sm. & Town) afford a basis for further study of the effect of this disease on the young and bearing orchard. The available data on this question are limited and largely based on experiments of short duration without a definite understanding of the cause of the disease.

This bulletin contains a record of progress in a study of the effect of crown gall upon an apple orchard from the time it is set out until it becomes of bearing age. The relative influence of various types of galls upon the annual growth of the trees has been considered and some data have been gathered on the amount and position of the galls in relation to the growth and percentage of stand in the orchard. Also, the susceptibility of certain kinds of apple trees to crown gall after they have been planted in the orchard, and the persistence of crown gall on infected trees have been noted.

Other lines of experiment in this investigation, including those dealing with control measures, will be reported later.

The authors wish to acknowledge the helpful co-operation rendered by Station Chiefs Buchanan, Beach, and Maney.

REVIEW OF LITERATURE.

The literature bearing on the influence of crown gall on the life of an apple tree has been quite exhaustively covered by Hedgecock (4) and Smith (5) so in this bulletin only a few of the most pertinent papers bearing directly on the work to be described will receive consideration.

Hedgecock (4) has probably studied the effect of crown gall on young apple trees more thoroughly than anyone else in America. However, it should be emphasized that subsequent to the time when the causal agent was definitely determined, no one apparently has given consideration to this problem. This fact should be kept constantly in mind when considering the results of the earlier workers.

A brief summary of Hedgecock's (4) work follows:

Orchard No. 1 was located near Louisiana, Missouri, on a piece of gently sloping upland consisting of heavy clay loam. Orchard No. 2 was planted in the same block as No. 1, but was lower, and wetter in rainy seasons. Orchards 1 and 2 were planted with trees of the following varieties: Ingram, Gano, Collins, and York Imperial, grown in a nursery in eastern Missouri. Orchard No. 1 was planted with 112 healthy apple trees and 96 diseased with hard crown gall, the galls being near the crowns of the trees just below the surface of the soil. Orchard No. 2 was planted with 122 healthy apple trees and 139 diseased trees in alternating rows. Thirty-six of the Collins variety in Orchard 2 had soft crown gall.

Orchards 1 and 2 were given ordinary care, cultivation being across the rows in No. 2 to insure spread of the organism and no fertilizer was used. The trees stood 8 by 9 feet. Owing to a fire, after eight years, the experiment had to be discontinued; that is, after they had grown for six years in the orchards.

The results showed that the healthy trees had developed in six years an increase in diameter of six one-hundredths of an inch greater than those diseased with hairy-root and twenty-nine hundredths of an inch greater than those diseased with crown gall. Out of the 234 healthy trees transplanted, 153 or 65.4 percent remained healthy; 23 or 9.8 per cent died; 11, or 4.7 percent developed traces of hard crown gall; and 47 or 20.1 percent showed traces of woolly-knot and aerial forms of hairy-root. Out of 235 apple trees diseased with crown gall at the time of transplanting to the orchards, 73, or 31.1 percent, entirely recovered from the disease; 30, or 12.8 percent, died; 63, or 26.8 percent, were diseased with the hard form of crown gall; and 69, or 29.3 percent, developed the woolly-knot form of hairy-root, chiefly from the surface of former hard galls.

Orchard No. 3 was destroyed by fire and no notes were taken.

Orchard No. 4 was planted on the Potomac Flats near Washington, D. C., in 1907 and transplanted to the experiment farm at Arlington, Virginia, in 1908. The trees of the Jonathan, Grimes and Gano varieties used were from a nursery in eastern Missouri. During the two years that had elapsed since planting only 8 had died in spite of the fact that they had been twice transplanted. Out of 225 healthy trees, 3 had died; of 82 trees diseased with hairy-root, 2 had died; and of 193 trees diseased with crown gall, 3 had died. The percentage remaining alive was but slightly in favor of the healthy trees.

Alwood (2) planted infected and healthy trees in the nursery and studied them after one season's growth. In his experiments, both healthy and diseased roots were procured from different sources. They were sorted into apparently healthy and apparently diseased stock. The plan pursued in this experiment was to use the apparently diseased seedlings as root stocks in comparison with the apparently healthy seedlings from the same sources. The apparently diseased roots were made into three cuts, viz.; top, middle, and tip pieces and healthy scion wood were set on these three pieces by the ordinary whip graft method. The number of grafts made up in this manner is not stated. All of the trees that grew developed crown gall during the first year, and all of the trees were weak.

As a check, healthy scion wood was set on apparently healthy roots and planted in the nursery adjoining the infected roots. The trees that grew made strong healthy trees free from crown gall in every case.

Alwood's experiments although limited and of short duration would tend to show that crown gall infested seedlings are quite undesirable stock to use for the propagation of apple grafts. Only weak trees result.

Butz (3) records a case where "Three-year-old trees infected with crown gall varying in size from a hickory nut to an unhulled walnut were set in an orchard in 1898. Five of these 11 trees were York Imperial, six Ben Davis. After being allowed to make two seasons' growth it was noted that two of the York Imperial had died and the other three had made only a weak slender growth. The six Ben Davis trees all grew but in every case the growth was short and weak. Observations made the following year showed that the trees were still making a weak growth. The galls had materially increased in extent and nearly girdled the trees at the collar." These data are of course valuable but it is unfortunate that Butz did not at the same time plant some normal trees as checks.

Stewart (7) records an interesting case where "In 1899 C. H. Stuart & Co. (nurserymen), Newark, N. Y., set out a crown gall experiment orchard of 500 trees, mostly Baldwins, all affected with crown gall. Under date of January 20, 1908, when the trees had been set nine years, Mr. Stuart wrote as follows: "These trees today show as good a growth as the trees planted the same time and free from crown gall. The bark is smooth, healthy in appearance, and the trees look thrifty and vigorous.' "

Stewart adds: "An experiment made by the (Geneva) Station bears on this point. In 1901 we planted 22 apple trees affected with crown gall to determine the effect of this disease upon the growth of the trees. The trees were three years old. The galls varied in size from one to two inches in diameter and were located mostly on the tap root, but in a few cases on lateral roots. Some of the trees had several galls each. We believe the galls were typical of those commonly found on apple trees in New York nurseries. Five of the trees were dug in 1903, five in 1905, and the remainder in 1907. In no instance was there any evidence that the galls had increased in size or number, or that they had been in any way injurious to the trees. Probably apple trees bearing large galls should be rejected but unaffected trees from the same lot may be planted without fear of bad results."

Stewart's experimental evidence is too limited to afford grounds for making definite statements.

METHODS OF THE EXPERIMENT BY THE IOWA STATION AND MATERIALS USED.

At the convention of the National Nurserymen's Association held in Denver, in 1910, a committee was appointed from its membership for the purpose of gathering experimental evidence as to injurious or non-injurious effects of crown gall upon apple trees. E. S. Welch, president of the Mount Arbor Nurseries, Shenandoah, Iowa, was one member of this committee. During 1911, he urgently requested the Pomology Section of the Iowa Experiment Station to cooperate with him in long time experiments to determine the effect of crown gall upon the growth and productivity of the apple.

It was finally arranged that a cooperative investigation along this line should be undertaken as a joint project by the Station Sections of Pomology and Bacteriology cooperating with the Mount Arbor Nurseries. In the spring of 1916 the bacteriologist relinquished his relations with this project to the pathologist who joined the Station staff at that time.

The authors gratefully acknowledge the helpful assistance rendered by Mr. Welch during this investigation. Without his assistance and enthusiastic support much of the data presented in this paper would not be available.

SELECTION OF TREES.

The Mount Arbor Nurseries furnished the trees used in these experiments and the land upon which they were planted. They have also cared for their cultivation since the beginning of the experiment. During the digging season of 1911, this company placed in their storage cellar for experimental use, a large number of normal trees and some that were infected with crown gall. Early in the spring of 1912, the senior author and the Station bacteriologist selected from these trees, 310 that were infected with crown gall and 246 normal trees for use in the experiment.

In selecting these trees, an effort was made to secure an average lot of diseased trees. Those which were badly galled were discarded as likewise were those which were but slightly affected. Unfortunately no attempt was made at that time to record the exact position of the gall and extent of injury upon each individual tree selected for experiment. The importance of this omission has since become very evident.

The land chosen for the experiment lay on a north slope. It was bordered on the south by an old scion orchard which has since proved to be very generally infected with crown gall. This piece of ground, consisting of about one acre, had previously been used for growing general nursery stock. The soil is a medium heavy clay composed of Missouri loess and a heavier clay mixture. It is good orchard soil.

The trees were planted rather late, about May 10, 1912, yet a good stand was secured.

The trees were set four by seven feet or at the rate of about 1,550 trees per acre with the intention of gradually thinning these out as they became crowded, making careful studies during the progress of the experiment on the development of the galls and their influence upon the tree growth. By 1916 one-half of the trees had been thus removed.

The list of trees planted was composed of the following varieties:

60 Wealthy infested with crown gall, ⅝-inch grade.
36 Wealthy normal, ⅝-inch grade.
140 Wealthy infested with crown gall, ½-inch grade.
90 Wealthy normal, ½-inch grade.
80 Jonathan, infested with hard gall.
130 Jonathan, infested with soft gall.
120 Jonathan, normal.

In selecting the trees for the experiment, it was noted that the Wealthy were all infected with hard galls and very little hairy root, while the Jonathan were infected with both hard and smooth galls and with softer galls having hairy root prevalent. In order to determine the effect of these two forms of galls on the Jonathan, two lots were selected, and designated as "Hard Gall" and "Soft Gall."

METHODS OF MEASURING TREE GROWTH.

In measuring the influence of crown gall upon the trees under experiment, four factors have been considered:

1. Annual increase in trunk diameter or caliper.
2. Twig length per tree.
3. Twig weight per tree.
4. Twig caliper, or diameter, as indicated by the weight per unit of length.

The twig length and weight were recorded only in 1914 and 1915.

The trees were not calipered individually at the time they were planted, but after the growth was completed in the fall of 1912, each individual tree was calipered at two places on the trunk; one approximately four and the other twelve inches above the collar or surface of the ground. Small broad nails were driven in the tree at these points so that all subsequent measurements might be taken at the same points. Each year, during the dormant season, the trees have been thus carefully calipered and a record has been made of their diameter, readings being recorded to the closest one-eighth of an inch. It is appreciated that such readings are not as absolutely accurate as might be desired, yet they form an excellent basis for comparison and give a reliable indication of relative tree growth.

In addition to these annual records of diameter, the orchard was thinned in the spring of 1915 and again in the spring of 1916 and more detailed measurements were made of the trees which were removed. In the spring of 1915 ten trees from each plot were dug. All of the twig growth of 1914 was carefully removed and its length measured to show the average length per twig and the total twig length per tree. These twigs were then weighed on a gram balance so that the total weight was obtained. From these data, computations were made showing the average twig weight per running foot. This gave a more accurate comparative measurement of twig diameter than could be secured by calipering the twigs.

In the spring of 1916, the trees in the orchard were becoming slightly crowded and were, therefore, systematically thinned to one-half of the original number, leaving alternate trees in adjacent rows so that the tree distance at the present time is about 8 by 8 feet. About two hundred and fifty trees

were thus removed and records were made in the same way as was done in the spring of 1915. The tables shown on the subsequent pages were made up from the data secured by these methods.

EXPERIMENT DATA.

The measurements which were made in recording the influence of crown gall upon the growth of the trees as already described are presented in tabular form in the following pages. The relation of the extent, position, and length of time trees have been galled, to the growth of the trees has also received consideration.

EFFECT OF CROWN GALL UPON ORCHARD STAND.

In the selection of trees for orchard planting the first consideration naturally is to secure trees that will live. By studying the data in Table I, one discovers rather surprisingly that the trees in this experiment which were affected with crown gall have produced a better stand in the orchard than did the normal trees.

TABLE I.—A COMPARISON OF THE ORCHARD STAND OBTAINED FROM NORMAL AND GALLED WEALTHY AND JONATHAN TREES.

Variety	No. trees planted 1912	Died				Total dead	Percentage stand 1915
		1912	1913	1914	1915		
Galled Wealthy	190	0	2	0	4	6	97
Normal Wealthy	115	11	2	0	2	15	87
Galled Jonathan	210	6	2	0	0	8	96
Normal Jonathan	100	3	2	0	0	5	95

Table 1 gives the number of trees planted in each block, the number dying each year up to and including 1915, the total number dead and the percentage stand remaining at the close of the season of 1915. It will be noted that there is ten per cent better stand in the galled Wealthy than in the normal Wealthy and one per cent better stand in the galled Jonathan than in the normal. In all probability there is some other factor than the disease to account for the great difference in stand shown in the Wealthy blocks. In this connection, it is of interest to call attention to results secured by Hedgecock (4) in the planting of apple grafts affected with hairy root. In all cases, he secured a better stand from such diseased seedling

roots than from normal ones. He suggests that because such hairy root trees have a larger number of small feeding roots they are, therefore, more apt to grow than are trees with normal roots.

It should be noted that the trees selected for planting in the normal Wealthy block were not as good a grade as those in the diseased lot. However, the data in Table I indicate that crown gall has little if any immediate detrimental effect so far as the stand is concerned.

INFECTION WITH CROWN GALL OF NORMAL APPLE TREES PLANTED IN AN ORCHARD.

It is, of course, well known in a general way that healthy trees may become infected with crown gall after being set in the orchard, but definite figures bearing on this question have been lacking. Information has been obtained bearing on this point in connection with the normal Wealthy and Jonathan used as checks in this experiment. As pointed out earlier in this bulletin the trees were set in land that was already infested with crown gall and furthermore healthy and galled trees were in some cases set in adjoining rows. Plate 1 Fig. 3 shows a tree that was normal when planted in 1912, but became infested before 1916.

Table No. II gives the number of normal trees planted in 1912, the number which remained normal when dug after the close of the season of 1915 and the number which had become infected with crown gall by the time they were dug. In the case of Wealthy 62 percent became infected during the four-year period while with the Jonathan only 13 percent became infected. This varietal difference in susceptibility to crown gall in the young orchard is much the same as in the nursery. It is well known by the nurserymen that blocks of Wealthy usually show more crown gall than do the Jonathan blocks.

PERSISTENCE OF CROWN GALL.

As might be expected, a certain number of the trees in the diseased blocks were able to recover from the effects of crown gall and to all appearances throw off all evidences of the disease. Such a tree is shown in Plate 3, Figures 3 and 4. Table III gives the percentage of trees that recovered.

TABLE II.—THE NUMBER OF TREES BECOMING INFESTED WITH CROWN GALL AFTER THEY WERE SET IN THE ORCHARD.

Variety	No. Normal Trees Planted 1912	No. Normal Trees, 1915	No. Galled Trees, 1915	Percentage Normal Trees Becoming Infested
Wealthy	39	15	24	62
Jonathan	38	33	5	13

At the time the trees were dug, only 8 percent of the galled Wealthy were free from galls, while there were 31 percent of the galled Jonathan that were free. It is interesting to note also that of those Jonathan trees which were selected as affected with hard gall, 36 percent recovered from the disease and showed no evidences thereof at the close of the growing season of 1915. Only 29 percent or 7 percent less, of those affected with soft gall recovered, indicating greater persistence of the soft gall type. It would seem, according to these results, that soft galls are more to be feared by the orchardist than the hard ones. This fact may also explain why some orchard men maintain that galled trees are as valuable as normal ones to set in an orchard.

TABLE III.—THE RECOVERY OF CROWN GALL INFESTED TREES AFTER BEING SET IN ORCHARD FOR FIVE YEARS.

Variety	Type of gall	No. Galled Trees Planted 1912, Dug 1916	No. Galled Trees, 1915	No. Trees Recovering	Percentage Trees Recovering
Wealthy	Hard and Soft	74	68	6	8.1
Jonathan	Soft	52	37	15	29.
Jonathan	Hard	25	16	9	36.
All Jonathan	Hard and Soft	77	53	24	31.

THE TRUNK GROWTH OF GALLED AND HEALTHY TREES.

As stated earlier in this bulletin the effect of crown gall was measured in at least four different ways: (1) trunk diameter, (2) twig length, (3) twig weight and (4) twig diameter. At first it was decided to use increase of trunk diameter as an index of the comparative rate of growth of the galled and normal trees. This proved later to be less accurate than the twig development as is well shown in Table IV.

The average size of the trees in the various plots at the close of each season is shown in Table IV as well as the annual and total increase for four years in the various plots. In this table no attempt is made to separate the trees into galled and normal at the time they were dug. The table includes all trees planted in each plot regardless of their condition at the close of the season of 1915.

It has already been shown in this bulletin that of apple trees which are infested with crown gall when planted, from 8 to 36 percent, depending upon the variety, may recover, in a period of five years. Likewise healthy trees may become

galled after being set in the orchard, while still others may continuously remain normal. The records of trees shown in Table V have been grouped into four classes as follows:

1. Those trees which were galled when planted in 1912, divided into two classes: those which did, "B," and those which did not recover, "A."

TABLE IV.—A COMPARISON OF THE EFFECT OF CROWN GALL UPON THE GROWTH AND INCREASE OF TRUNK DIAMETER OF GALLED AND HEALTHY TREES FOR FOUR YEARS.

Variety	1912		1913			1914			1915			1913 1915
	No. Trees	Diam.	No. Trees	Diam.	Diam. Inc.	No. Trees	Diam.	Diam. Inc.	No. Trees	Diam.	Diam. Inc.	increase
Galled Wealthy	189	.534	188	.757	.223	188	.974	.217	169	1.269	.295	.735
Normal Wealthy	88	.576	88	.829	.253	88	1.095	.266	82	1.394	.299	.818
Galled Jonathan	203	.561	202	.726	.165	202	1.022	.296	182	1.455	.433	.894
Normal Jonathan	97	.592	95	.838	.246	95	1.228	.390	85	1.680	.452	1.088

2. The trees which were normal when planted in 1912, divided into two classes: those becoming infected, "C," and those which remained normal, "D," when dug in the fall of 1915.

In the diameter increase for 1914, a gradual progression is found from those which were galled throughout the experiment to those which remained normal for the same period, with the exception of the one Wealthy tree which was galled

TABLE V.—EFFECT OF CROWN GALL UPON THE TRUNK GROWTH OF APPLE TREES THAT ARE GALLED WHEN SET AND RECOVER AS COMPARED WITH NORMAL ONES THAT BECOME INFESTED, WITH CHECKS REMAINING NORMAL.

Variety	Condition when planted 1912	Condition when dug	No. of trees	Diameter increase 1914	No. of trees	Diameter increase 1915
A. Wealthy	Galled	Galled	15	.20	68	.29
B. Wealthy	Galled	Normal	1	.13	6	.33
C. Wealthy	Normal	Galled	5	.29	24	.30
D. Wealthy	Normal	Normal	5	.33	15	.36
A. Jonathan	Galled	Galled	20	.27	52	.42
B. Jonathan	Galled	Normal	0	----------	24	.44
C. Jonathan	Normal	Galled	4	.39	5	.51
D. Jonathan	Normal	Normal	6	.42	26	.44

and became normal. This individual tree should hardly be considered in a table of this kind.

The diameter increase in 1915 shows the same relative progression with the same exception. Here there are six Wealthy trees and some reason other than the small number of trees must account for this variation. Another exception is found in the Jonathan trees, namely those which were normal and became infected show a larger diameter increase than those which were normal throughout the life of the experiment. The five trees listed, however, were not badly infected at the time they were dug and were recorded as vigorous trees.

A slightly greater variation is found in the 1915 growth as shown in Table IV, where all trees planted in the galled plot are considered together and those which were planted in the normal plots included together.

The differences as shown in Tables IV and V seem almost trifling, but when stated in terms of twig growth such is no longer the case. The contrast is quite striking as shown in the following computations.

All trees of each variety regardless of crown gall infection were classified according to the amount of trunk diameter increase in 1915. For example all trees which gained one-fourth of an inch in trunk diameter were listed in one class, those which gained three-eighths of an inch in another class and so on for all trees dug in the spring of 1916. The average twig development per tree for each of these classes was found by averaging the twig measurements of all trees in the class.

By taking the classes of Wealthy .3125 inches and .375 inches most closely corresponding to Table V, A .29 inches and D .36 inches respectively, and by comparing the proportionate gain which classes A and D would produce, the normal Wealthy D for only .07 inches difference in trunk diameter increase would make a growth of 80 inches in twig length and 55 grams in twig weight more than would the galled Wealthy "A." The results of this computation are given in Table VI.

TABLE VI.—THE RELATION OF TRUNK AND TWIG GROWTH IN WEALTHY TREES.

	Class as Per Gain in Trunk Diameter, 1915—	Average Twig Length Produced Per Tree, 1915—	Average Twig Weight Produced Per Tree, 1915—
	Inches	Inches	Grams
Class with	.3125	676.6	291.3
Class with	.375	748.	340.5
Table V "A"	.29	650.9	273.6
Table V "D"	.36	730.8	328.7
Gain "D" over "A"	.07	79.9	55.1

A similar computation for the normal Jonathan shows .02 inches difference in trunk diameter increase, a gain of 124 inches in twig length and a gain of 51 grams in twig weight over that produced by the galled Jonathan.

It is also important to recognize that the twig growth could be much more accurately measured for the reason that the twig length totaled hundreds of inches per tree while the trunk diameter increase did not exceed a fraction of an inch; also the computations were made from so large a number of twigs that the factor of error in these measurements was reduced to a minimum; whereas the trunk diameters were only recorded to the closest one-eighth of an inch and with but one measurement per tree.

It would seem that twig growth is a much more accurate and valuable index of the effect of crown gall than is trunk growth. In the remaining tables, twig growth and weight, only, are used.

EFFECTS OF VARYING AMOUNT OF CROWN GALL UPON THE TWIG GROWTH OF YOUNG APPLE TREES.

It seems quite well established under the conditions of this experiment that the length of time that apple trees are infected with crown gall is directly manifested in terms of growth either as diameter of trunk, or weight, length, or diameter of twig.

The question now arises as to what may be the influence of galls of different size. Is a small gall as serious a menace to the life of the tree as a large one and does it make any difference on what part of the tree the galls occur?

Data were collected bearing on these queries when the trees, which had been set for five years, were dug in the spring of 1916. At this time each individual tree was examined and a record made of the size and of the location of the gall upon the tree. The extent of the gall or galls was arbitrarily classified as little galled, medium galled, badly galled and normal. It has already been shown that a certain percentage of galled trees recover within the first three to five years after they are set. Also that normal trees may become infected within this same period. The classification as to the size of the galls does not take this matter into consideration, due to the fact that the period a given tree was infested with crown gall could not be determined under the condition of this experiment.

Again there were no determinations made as to what galls contained *Bacterium tumefaciens* in an active state. As a result, the data presented cannot be as accurate as desired but it does serve to show something as to the effect of crown gall upon growth.

The normal Jonathan trees in 1915, according to Table VII,

TABLE VII.—A COMPARISON OF VARYING EXTENT OF GALLS UPON THE TWIG GROWTH OF YOUNG APPLE TREES, DURING 1915.

Variety and Size of Galls	Average Twig Length Per Tree		Average Twig Weight Per Tree	
	No. trees	Inches	No. trees	Grams
WEALTHY				
Normal	18	859.2	18	389.7
Little galled	24	658.4	24	291.2
Medium galled	38	636.6	38	214.1
Badly galled	19	605.	19	243.6
JONATHAN				
Normal	50	1807.3	47	662.5
Little galled	25	1802.	25	631.5
Medium galled	12	1466.	11	519.4
Badly galled	17	1145.5	13	435.3

averaged 1807.3 inches twig growth weighing 662.5 grams, while badly galled ones produced 1145.5 inches, weighing 435.3 grams. In the case of the Wealthy the normal trees produced 859.2 inches, weighing 389.7, while the badly galled grew 605 inches, weighing 243.6 grams.

A comparison of the normal trees with those recorded as badly galled naturally gives the two extremes as shown in Table VII. The trees classified as medium and little galled do not show the striking differences one might naturally expect. This may be due in part to the arbitrary classification used, to the age of the gall, or to other unknown factors. The data presented in this table relating to the medium and little galled classes suggest that up to a certain point crown gall may not be seriously injurious. But be this as it may, the difference is marked in the growth of the normal and badly galled, which is the important contribution in this study.

It should be further noted that the data presented in this table are for twig growth during the season of 1915 when, owing to quite favorable weather conditions, the weaker trees were enabled to more nearly equal the normal trees in the amount of their growth. Future data of a similar character, if secured following a dry season, would perhaps show a greater variation between the little galled and normal trees.

Table VIII shows the effect of crown gall upon twig growth as indicated by the trees which were dug after the close of the 1914 and 1915 seasons. It shows a much greater advantage of the normal trees over the galled trees in 1914 than is shown by the 1915 growth. In the case of the Jonathan normal there is a gain of 94 per cent in twig length produced over the galled Jonathan. It should be noted in this connection that the sea-

TABLE VIII.—A COMPARISON OF THE TWIG GROWTH OF GALLED AND NORMAL TREES.

Variety	Growth Third Season						Growth Fourth Season					
	No. trees	Average twig length—inches	Percentage gain	Average twig weight per tree gram	Percentage gain		No. trees	Average twig length—inches	Percentage gain	Average twig weight per tree gram	Percentage gain	
Galled Wealthy	17	296.2	------	144.8	------		74	627.8	------	271.8	------	
Normal Wealthy	14	430.54	45	231.5	59		39	792.5	25	372.4	37	
Galled Jonathan	20	643.62	------	256.4	------		76	1566.5	------	558.	------	
Normal Jonathan	10	1250.4	94	651.89	154		24	2090.	33.4	768.	42	

son of 1915 was very moist, a season of extremely heavy rainfall, thus greatly assisting the galled trees in overcoming the difference which might otherwise have been shown during a dry season.

Fig. 1. Comparison of weight per tree of twigs produced in 1914.
A—diseased when planted.
B—normal when planted.
1—diseased when dug.
2—normal when dug.

There was a gain in twig growth during the fourth season by the normal trees, as compared with the diseased trees, of 37 percent in the case of Wealthy and 42 percent in the case of Jonathan. The comparative twig growth of gall and normal trees is shown in Plate VII for both Jonathan and Wealthy.

This evidence would indicate that up to bearing age there is a decided advantage in favor of planting sound, healthy trees. This table does not show the comparative growth of normal and diseased trees alone, for when considered from this standpoint a part of the trees, as shown in Tables IX and X fall under a different classification from that shown in Table VIII. For example, in the normal Wealthy blocks which show in 1915 an advantage over the diseased blocks of 37 percent in weight produced, a large percentage of the trees became infected while in the diseased block only 8 percent threw off the disease. By glancing at Table X it will be noted that those trees which remained normal throughout the four years' growth showed a gain of 51 percent in twig growth in 1915 over those which were galled throughout the four years' growth.

TABLE IX.—THE RELATIVE EFFECT OF CROWN GALL UPON TWIG GROWTH OF APPLE TREES GALLED OR NORMAL FOR VARYING LENGTHS OF TIME.
Third Season's Growth 1914.

Variety	Condition when planted 1912	Condition 1914	No. trees	Average twig growth—inches	Percentage growth A-100%	Average twig per tree gram	Percentage A-100%
A. Wealthy	Galled	Galled	16	300.2	100	153.6	100
B. Wealthy	Galled	Normal	1	252.	84	142.	92
C. Wealthy	Normal	Galled	5	414.8	138	212.2	138
D. Wealthy	Normal	Normal	9	454.4	152	263.3	171
A. Jonathan	Galled	Galled	20	643.6	100	256.4	100
B. Jonathan	Galled	Normal	0				
C. Jonathan	Normal	Galled	4	1102.	171	458.7	178
D. Jonathan	Normal	Normal	6	1661.5	258	780.6	304

Table IX is presented to indicate the influence which the gall had upon the trees where it remained throughout the period of the experiment and its influence where it remained for only a short time or where normal trees became galled after planting. The comparative twig weights are shown in figure 1. There were too few trees in 1914 which became normal to give any indication of this effect. Omitting this class "B," as shown in the table IX, there is a gradual progression in the total twig length produced in 1914 in the Wealthy from 300 inches in the galled Class "A" to 454 inches in the normal Class "D," a gain of 158 percent in the latter case.

This data, although limited, points clearly to the fact that galled trees in the third season of their growth do not grow nearly as rapidly as normal trees.

The gain in 1915 of the normal Class "D" over galled Class "A" during a wet season, as shown in Table IX, is not so great as might be expected, although in the case of the Wealthy the gain is very nearly the same. In this case, however, there are a sufficient number of trees which were galled and became normal to indicate that those trees made a larger growth than those which remained galled throughout the life of the experiment.

The orchardist is primarily interested in the growth his trees will make after planting and is therefore interested in securing trees that will make the best growth regardless of the development of, or the recovery from the crown gall infection. Evidence along the line of the desirability of planting normal trees or galled trees and the resulting growth that one might expect in such blocks is shown in Table X.

This evidence is presented from two standpoints, first, from the standpoint of the condition of the trees when planted as shown in Table VIII and second, from the standpoint of the condition of the trees both at planting time and when dug as shown in Tables X and XI.

TABLE X.—GROWTH FOURTH SEASON, 1915.

Variety	Condition when planted 1912	Condition 1915	Average twig growth—inches	Percentage growth A-100%	Average twig weight—grams	Percentage A-100%
A. Wealthy	Galled	Galled	619.5	100	265.3	100
B. Wealthy	Galled	Normal	722.	117	343.5	129.5
C. Wealthy	Normal	Galled	776.8	125.4	364.6	137.4
D. Wealthy	Normal	Normal	936.9	151.2	449.	169.2
A. Jonathan	Galled	Galled	1537.5	100	561.8	100
B. Jonathan	Galled	Normal	1629.8	106	548.7	97
C. Jonathan	Normal	Galled	1972.7	122	708.5	126
D. Jonathan	Normal	Normal	2113.6	137	821.2	146

The "A" Wealthy and Jonathan are those trees that were galled and never recovered. The "B" trees are those that were galled but later recovered. The "C" trees are the normal trees that became galled after being set, while the "D" trees are the trees that were healthy when set and remained free from crown gall during the period indicated.

The production of a greater twig length would not be conclusive evidence of larger growth if considered apart from the caliper of those twigs or the total twig weight.

TABLE XI.—EFFECT OF CROWN GALL UPON TWIG DIAMETER AS INDICATED BY WEIGHT PER RUNNING FOOT OF TWIG LENGTH.

Variety	Condition when planted	Condition when dug	No. trees	Weight per ft. 1914 growth—grams	No. trees	Weight per ft. 1915 growth—grams
A. Wealthy	Galled	Galled	16	6.15	66	4.97
B. Wealthy	Galled	Normal	1	6.76	6	5.67
C. Wealthy	Normal	Galled	5	5.68	24	5.52
D. Wealthy	Normal	Normal	9	6.88	14	5.66
A. Jonathan	Galled	Galled	20	4.64	47	4.04
B. Jonathan	Galled	Normal	0	----------	22	4.02
C. Jonathan	Normal	Galled	4	4.66	14	4.66
D. Jonathan	Normal	Normal	6	5.85	19	4.47

Table XI is presented to indicate the caliper of those twigs measured in 1914 and 1915. The evidence shown here is practically the same as that shown by the twig length and the trunk diameters. There is a decided advantage in favor of the trees which remained normal throughout the experiment over those which remained galled. This is graphically shown in figures 2 and 3. There are, as might be expected, slight variations in the other two classes "B" and "C" but the same general trend is shown. The important evidence in these tables VIII to X inclusive, is shown in classes "A" and "D" where the condition of the trees throughout their lives is known. Emphasis should be placed upon these classes and

Fig. 2. Comparison of weight per tree of twigs produced in 1915.
A—diseased when planted.
B—normal when planted.
1—diseased when dug.
2—normal when dug.

not upon classes "B" and "C." In addition to producing greater twig length as well as a larger number of twigs, they were heavier per unit of length.

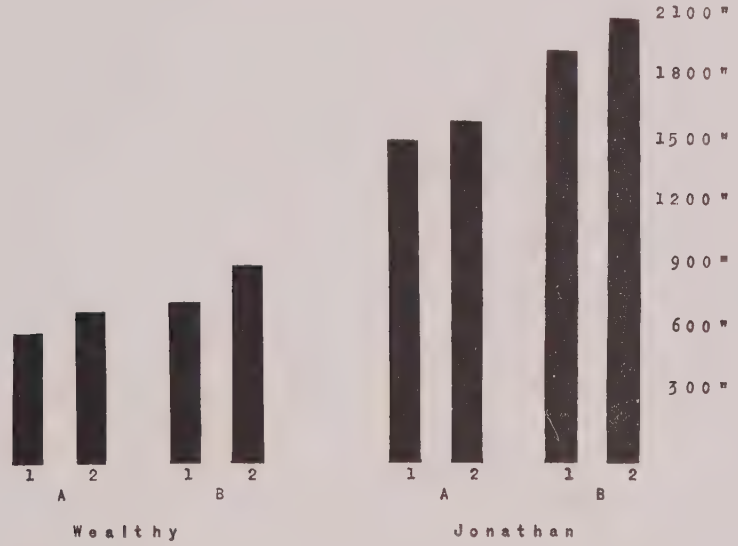

Fig. 3. Comparison of average twig growths per tree during 1915.
A—diseased when planted.
B—normal when planted.
1—diseased when dug.
2—normal when dug.

THE RELATION OF THE POSITION OF THE GALL UPON THE GROWTH ACTIVITIES OF APPLE TREES.

The question as to the influence of the position of the gall upon the growth activity of the tree was next considered. When the extent of the galls was determined their location on the plant was also recorded. In the great majority of the 195 trees examined the galls were on the underground parts of the tree. The infected trees were put into four groups; galls on the stock, union, collar, and secondary roots. In some cases trees had galls both at the union and on the stock or collar or vice-versa.

It should be explained that the trees classified as galled on stock are those trees which were galled below the union on root used as a stock. Those recorded as being galled at the union are those which were galled where the stock and scion united. No distinction was made whether the gall had its origin at this point on the stock or on the scion. Those recorded as galled at the collar are those galled at or near the sur-

face of the ground above the graft union. Those recorded as galled on the secondary roots are those trees which had galls on the small secondary roots and not on the main root stock.

The data in Table XII indicates that the galls occurring on the secondary roots are probably less harmful than those occurring on the stock, union, or collar. In the Jonathan the trees galled on the collar showed only an average twig growth of 1200 inches while the normal trees gave 1807 inches. On the Wealthy on the other hand the trees galled at the stock averaged 580 inches, while the normal ones averaged 859.2. In this variety it should be pointed out also that the trees galled at the collar exceeded the normal ones in growth; however, the number of trees studied was only five which may well account for the irregularity.

TABLE XII.—EFFECT OF POSITION OF CROWN GALL INJURY UPON GROWTH ACTIVITIES.

Position of Gall	No. Trees	Average Twig Growth in Inches	No. Trees	Average Weight in Grams
JONATHAN				
On Stock	19	1706.4	18	622.
At Union	26	1472.8	24	508.7
At Collar	8	1200.2	6	517.6
On Secondary Roots	5	2005.	5	710.6
Normal	50	1807.	47	662.5
WEALTHY				
On Stock	41	580.2	40	255.33
At Union	43	656.2	42	278.1
At Collar	5	884.1	5	481.7
On Secondary Roots	4	813.5	4	389.
Normal	18	859.2	18	289.7

Be this irregularity as it may, this fact is clear, that galls on the stock and union do, in the majority of cases interfere with the normal growth of the tree. It is further evident that galls on the secondary roots are not as injurious as when found growing on the stock or scion. The data presented in this paper do not allow a definite statement regarding the comparative effect of galls on the stock or union.

An interesting observation should be mentioned in this connection, namely, that on many of the trees which were badly galled a considerable number of fruit spurs were found in the spring of 1916 while none were found on the healthy trees. This suggests that this condition was caused by the severe crown gall infestation. Trees of this kind are shown in Plate I, fig. 1; Plate IV, fig. 3; and Plate VI, fig. 1 and 5. This early production of fruit spurs may be a valuable symptom for diagnosis of severe crown gall infestation of the underground portions of the plant. Before definite statement can be made on this point, further observations and data are necessary.

THE COMPARATIVE EFFECT OF HARD AND SOFT GALL ON YOUNG JONATHAN TREES.

The question is often asked as to which is the more injurious to young apple trees, hard or soft galls. When the Jonathan trees used in this experiment were selected for planting in 1911, a certain number were infested with either hard or soft galls. These trees were allowed to stand until 1915 when they were dug and the twig growth measured .

Hard Gall: Twig length per tree 1755.5 in.: twig weight 664. gm.

Soft Gall: Twig length per tree 1468.3 in.: twig weight 552.7 gm.

Normal: Twig length per tree 2113.6 in.: twig weight 821.2 gm.

It seems evident from the data at hand that soft galls are more injurious to young trees than hard galls for the first four years after being set in an orchard. It is further evident as pointed out earlier that both hard and soft galls influence materially the growth of young as compared with older trees.

SUMMARY.

In the experiments recorded in this bulletin on the effect of crown gall on apple trees, two of the leading commercial varieties of apples common in Iowa have been employed, namely, Wealthy and Jonathan. The orchard was set in 1912 at Shenandoah, Iowa, on a modified Missouri loess type of soil, using two year old "cut back" trees for planting.

Under the conditions of the experiment described, at the end of five years more of the crown gall infected apple trees were alive than normal trees.

Although the stand for the first four years was better on the crown gall than on the normal block yet the records taken after the severe winter of 1916-17 show that the stand of the Jonathan in the crown gall block was reduced from 96 percent to 91 percent as compared to a 95 percent stand in the normal block.

The experiment confirms the general idea that Wealthy is more susceptible to crown gall than Jonathan. When apparently normal Wealthy and Jonathan trees were set in this orchard 62 percent of the Wealthy became infected and 13 percent of the Jonathan.

In this experiment galled trees did not grow nearly as rapidly as normal trees. Those which were galled when set and later recovered made a greater growth than those that did not recover from the galls.

The data presented show that crown gall greatly retards the growth activities of young apple trees. It is followed by a reduction in the amount of increase in trunk diameter, and in the number of twigs, their length, their thickness and their weight.

The amount of injury is affected by the length of time the tree has been galled and by the location and extent of the injury.

The experiment has not yet covered the activities of trees of bearing age.

It is clear that twig measurement is a much more accurate and valuable index of the effect of crown gall than trunk diameter growth.

Large galls seemed to be more injurious than small ones. Small galls on underground portions of the tree did not seem to injure materially the twig growth.

Fruit spurs develop earlier on the badly galled than on the normal trees.

Galls on the stock and union seemed to be equally harmful.

Galls on the secondary roots were less harmful than those occurring on the union or stock.

Hard galls were less injurious than soft galls.

LITERATURE CITED.

(1) ALDERMAN, W. H.
1915. The fertilization of peach orchards. Bul. West Va. Agr. Exp. Sta. 150: 3-39.

(2) ALWOOD, WM. B.
1902. Orchard studies XIII. Some observations on crown gall of apple trees. Bul. Va. Agr. Exp. Sta. 140: 187-212.

(3) BUTZ, GEO. C.
1902. Crown gall. Ann. Rep. Pa. State College, 405-414.

(4) HEDGECOCK, GEO. G.
1910. Field studies of the crown gall and hairy-root of the apple tree. Bul. U. S. Dept. Agr., Bur. Plant Indus. 186: 3-108.

(5) SMITH, ERWIN F., BROWN, NELLIE A., and TOWNSEND, C. O.
1911. Crown gall of plants; its cause and remedy. Bul. U. S. Dept. Agr. Bur. Plant Indus. 213: 3-215.

(6) STEWART, JOHN P.
1915. Experimental results in young orchards in Pennsylvania. Bull Pa. Agr. Exp. Sta. 134: 3-20.

(7) STEWART, JOHN P.
1910. The fertilization of apple orchards. Bul. Pa. Agr. Exp. Sta. 100: 3-28.

(8) TOUMEY, J. W.
1900. An inquiry into the cause and nature of crown gall. Bul. Ariz. Agr. Exp. Sta. 33: 3-64.

PLATE I.

Fig. 1. Four year old Jonathan apple tree infested with crown gall, from 1912 to 1916 when the photograph was taken. The tree was practically girdled near the surface of the soil. It was small and showed scanty twig development. Several flower clusters in the spring of 1916 indicated early bearing.

Fig. 2. Four year old Jonathan apple tree infested with crown gall 1912 - 1916. Illustrating the nature of the injury as seen in the field. Note "Hairy root" in Figures 2 and 4.

Fig. 3. Four year old Jonathan apple tree. Normal when planted spring of 1912, but infested with crown gall spring of 1916 when photograph was taken. Larger, better developed tree than that shown in Figure 1.

Fig. 4. This is the same tree as shown in Figure 1, showing the nature of the gall in greater detail.

PLATE II.

Fig. 1. Four year old Wealthy tree. Normal 1912 to 1916. Only fairly well developed root system.
Growth 1915—Trunk diameter .31 inches.
Twig length 984.00 inches.

Fig. 2. Root system of same tree as shown in Figure 1.

Fig. 3. Four year old Wealthy tree. Galled 1912 to 1916. Large gall 80% girdling the trunk. Note profusion of sprouts from root and above union on scion.
Growth 1915—Trunk diameter .25 inches.
Twig length 558.5 inches.

Fig. 4. Detailed illustration of the root system of the tree shown in Figure 3.

PLATE III.

Fig. 1. Four year old Jonathan tree. Normal 1912 to 1916. Well developed tree.
Growth 1915—Trunk diameter .50 inches.
Twig length 2624.00 inches.

Fig. 2. Root system of tree shown in Figure 1.

Fig. 3. Four year old Jonathan tree. Galled when planted 1912. Normal when dug spring 1916. An excellent tree. Entirely recovered from infestation.
Growth 1915—Trunk diameter .44 inches.
Twig length 2238.5 inches.

Fig. 4. Root system of tree shown in Figure 3.

PLATE IV.

Fig. 1. Four year old Jonathan apple tree. Galled when planted spring 1912. Practically free from gall spring 1916. Fairly good tree, with only small gall. No blossom buds.
Growth 1915—Trunk diameter .50 inches.
Twig length 2000.00 inches.

Fig. 2. Root system of tree shown in Figure 1.

Fig. 3. Four year old Jonathan apple tree. Galled when planted 1912. Badly galled spring 1916. Large gall above graft union on scion. Stock and primary root practically free from gall. This small poorly developed tree had forty blossom buds spring 1916 and was perceptibly more advanced than were the normal trees.
Growth 1915—Trunk diameter .44 inches.
Twig length 441.5 inches.

Fig. 4. Root system of tree shown in Figure 3. Gall practically girdling tree.

PLATE V.

Fig. 1. Four year old Wealthy apple tree. Galled when planted spring 1912. Badly galled spring 1916. Very large gall girdling the tree, slightly hairy. Poorly developed root system. Tree only fair.
Growth 1915—Trunk diameter .25 inches.
Twig length 436.5 inches.

Fig. 2. Root system of tree shown in Figure 1.

Fig. 3. Four year old Jonathan apple tree. Galled when planted spring 1912. Badly galled 1916. Large gall of hard type girdling the tree at the graft union. Some tendency toward hairy root type.

Secondary galls are numerous. Tree good condition considering extent of injury.
Growth 1915—Trunk diameter .44 inches.
Twig length 1137.00 inches.

Fig. 4. Root system of tree shown in Figure 3. Good root system with numerous roots above the graft union.

PLATE VI.

Fig. 1. Four year old Jonathan apple tree. Galled when planted spring 1912. Galled spring 1916. Not badly galled but above "Medium" class. Gall at base of scion and on primary and secondary roots. Tree is about one-half girdled. The tree produced seven blossom buds in 1916.
Growth 1915—Trunk diameter .25 inches.
Twig length 614.00 inches.

Fig. 2. Root system of tree shown in Figure 1.

Fig. 3. Four year old Jonathan apple tree. Galled when planted spring 1912. Badly galled at base of stock spring 1916. Four distinct galls. Poorly developed root system.
Growth 1915—Trunk diameter .31 inches.
Twig length 1313.00 inches.

Fig. 4. Root system of four year old Jonathan apple tree. Badly galled with but little more root system than shown.
Growth 1915—Trunk diameter .25 inches.
Twig growth 234.5 inches.

PLATE VII.

Fig. 1. Four year old Jonathan apple tree. Galled when planted spring 1912. Badly galled 1916. Galled on stock, scion and primary root. Tree produced ten fruit buds 1916.
Growth 1915—Trunk diameter .19 inches.
Twig length 247.00 inches.

Fig. 2. Root system of tree shown in Figure 1.

PLATE NO. VIII.

1915 Twig Growth.

(1) Normal Jonathan .....2624 inches
(2) Galled Jonathan .....1313 inches
(3) Normal Wealthy ..... 984 inches
(4) Galled Wealthy ..... 436 inches

PLATE I.

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

PLATE II.

Fig. 1.

Fig. 3.

Fig. 2.

Fig. 4.

PLATE III.

Fig. 1.

Fig. 3.

Fig. 2.

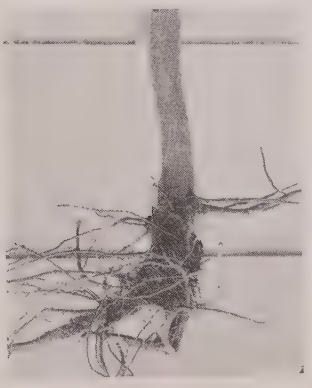

Fig. 4.

PLATE IV.

Fig. 1.

Fig. 3.

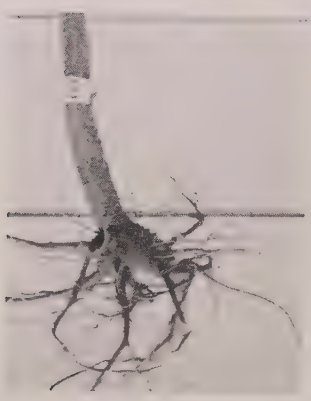

Fig. 2.

Fig. 4

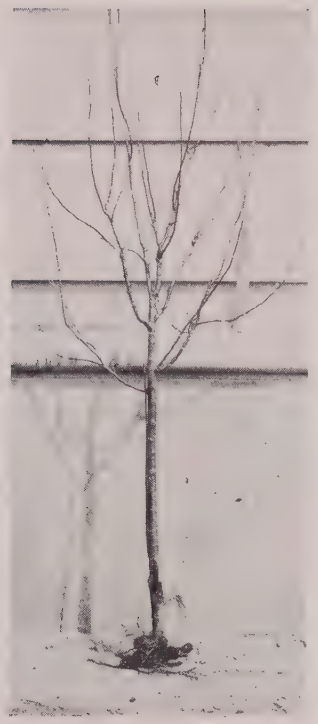

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 1.

Fig. 3.

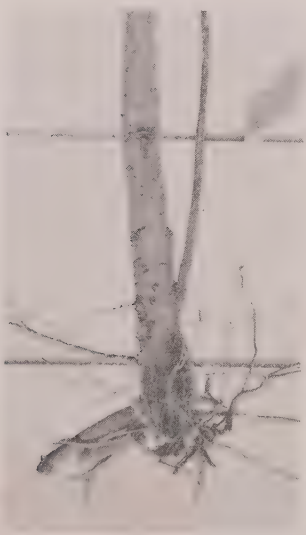

Fig. 2.

Fig. 4.

PLATE VII.

Fig. 1.

Fig. 2.

PLATE VIII.